PREVALENCE OF COCCIDIA IN GAME-FARM
REARED PHEASANTS IN IOWA

An abstract of a Thesis by
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The problem. The present study was undertaken in order to obtain information concerning the kinds of coccidian species harbored by pheasants raised under game-farm conditions, and to determine the levels of infection of the coccidian species found.

Procedure. Fecal samples collected from a mixed flock of 450 game-farm reared, adult ring-necked pheasants during a 20 week period beginning January 21, and ending June 3, 1973, were examined for coccidian oocysts. The number of oocysts per gm. of feces was determined for each week's sample by using a modified McMaster's helminth egg counting technique, and the proportion of the *Eimeria* species present in the block was determined by performing differential counts of the samples collected. One-hundred newly hatched pheasant chicks were also sampled for coccidian oocysts during a 5 week period beginning May 5, and ending June 3, 1973. The samples taken from the young birds were processed in a manner similar to that for the adult birds.

Findings. Only four of the eight recognized species of Eimeria reported to infect the pheasant were found to be present in this study. They are *Eimeria phasiani*, *E. pacifica*, *E. duodenalis*, and *E. tetartooimia*. *E. phasiani* and *E. pacifica* were the most prevalent species in the adult birds each averaging 42.0 percent of the mean differential counts for the entire survey. *E. tetartooimia* and *E. duodenalis* were the next most prevalent species averaging 10.5 and 4.0 percent of the mean differential counts, respectively. *E. phasiani*, alone, dominated the differential counts of the samples taken from the young birds and occurred with 75.0 to 94.0 percent frequency. *E. pacifica*, *E. tetartooimia*, and *E. duodenalis* were the next most prevalent, respectively, all with percentages below 10. A small number of coccidian oocysts resembling those of *Isospora lacazei* were also found but these were considered to be contaminants from passeriform birds.

Conclusions. As stated in the findings, four species of *Eimeria* and one of *Isospora* were found to be present in the ring-necked pheasants of this study. Oocyst production

appeared to vary with the climatic conditions; if the climatic conditions were stable, the oocyst production was relatively stable, but if the climatic conditions were abruptly altered, the oocyst production appeared to increase. Immunity appeared to be well established in the young birds within 5 weeks after hatching and apparently a state of premunition existed within the hosts by this time.

Recommendations. The epidemiological factors influencing coccidian infections are relatively unstudied. Investigations which attempt to analyze the influence of these factors on the etiology of coccidian infections should be of value not only from an academic point of view, but also from a practical point of view, namely, the control of the disease.

PREVALENCE OF COCCIDIA IN GAME-FARM REARED PHEASANTS IN IOWA

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INTRODUCTION AND REVIEW OF THE LITERATURE

Presently, eight species of *Eimeria* are known to parasitize the ring-necked pheasant, *Phasianus colchicus* (Todd and Hammond, 1971; Wacha, 1973). Previous studies of coccidian infections in pheasants have dealt primarily with those problems related to pathogenicity, chemotherapy and the cytology of the life cycle stages. However, these studies have provided little detailed information with regard to the epidemiological aspects of coccidiosis in pheasants, and particularly those pheasants raised under game-farm conditions.

Since the coccidia are known to be important parasites of gallinaceous birds (Levine, 1961), a study of the prevalence of coccidiosis in game-farm reared pheasants may contribute to our understanding of the significance of coccidiosis as a disease in pheasants.

Therefore, the objectives of the present study were to provide information concerning the kinds of coccidian species harbored by a flock of pheasants raised under game-farm conditions, and to determine the levels of infection of these coccidian species in such a flock.

M'Fadyean (1894) examined six young pheasants in England from a group of birds which exhibited a high mortality rate. All six birds were about one month of age and were suffering from diarrhea. Microscopic examination of the intestinal fluid and the walls of the small and large intestine of these sick pheasants revealed a heavy infection with a coccidium whose oocysts averaged about 30 micrometers in length. This study appears to be the first to report coccidiosis in the pheasant. No quantitative data was presented with regard to the epidemiology of the parasites found, however.

Tyzzer (1929) reported some of the details of the life cycle of *Eimeria phasiani*. He described the sporulated oocysts and determined that the endogenous stages occurred throughout the small intestine and the cecum. Tyzzer also reported that a strain of *Eimeria dispersa*, normally found in quail and turkeys, was capable of parasitizing the ring-necked pheasant.

Christiansen (1935) concluded that coccidiosis was an important disease in both wild and game-farm reared pheasants in Denmark, but he did not identify any of the coccidian species found in the pheasants he studied.

Yakimoff and Matschoulsky (1937) described the sporulated oocysts of *Eimeria langeroni* from *Phasianus colchicus chrysomelas*, a pheasant occurring in Russia. However, no mention was made by these authors regarding the prevalence of this species in the population sampled.

Eimeria phasiani, *E. pacifica*, *E. megalostomata*, and an *Eimeria* species referred to as "Type IV", were found by Ormsbee (1939) in a field study of the coccidia parasitizing the pheasants of eastern Washington State. In his study, Ormsbee concluded that the incidence of infection with these species was very low in wild populations since only 15 of the 37 birds studied were found to be infected with coccidia. Beyond this, however, no other quantitative data was presented in regard to the coccidian infections found.

Haase (1939) redescribed the sporulated oocysts of Eimeria phasiani from experimentally infected pheasants in Germany. No mention was made, however, regarding the epidemiology of the parasites.

Madsen (1941) reported that three species of coccidia, which he did not name, were common parasites of 169 adult pheasants and 67 juvenile birds in Denmark. He reported that 82 percent of the adult pheasants and 73 percent of the juveniles were infected with coccidia and that the infections were generally much heavier in the younger birds. While the incidence of infection with coccidia was of primary importance, no mention was made regarding the kinds of species present, the conditions under which the birds were raised or the general epidemiology of the coccidian infections found.

According to Davies, Joyner, and Kendall (1963), McCullough, in a private communication with the authors, stated that he isolated oocysts of an Eimeria species from the ceca of young pheasants in Edinburgh, Scotland. These oocysts were about 28.9 by 18.6 micrometers in size and were described as being broadly ovoidal in shape. Norton (1967b) referred to this species as "Ex ceca." Other than this, nothing else appears to be known about the *Eimeria* sp. reported by McCullough.

Jones (1964, 1965, and 1966) reported that 34, 33, and 38 percent, respectively, of the pheasants examined during a survey of game bird diseases in England, harbored *Eimeria* species. But again, no quantitative data was presented with regard to the kinds of species present or the level of infections in the birds examined.

Norton (1967a) described *Eimeria duodenalis* from English covert pheasants, and conducted a detailed study of the parasite's life cycle, host specificity and response to chemotherapy. His results showed that *E. duodenalis* was highly host specific, moderately pathogenic, and that preventive treatment appeared to be the most effective way of combating the organism.

Norton (1967b) did a similar study with *Eimeria colchici*, which he also described as being new to science. This parasite differed from the other species reported from pheasants with respect to its host specificity and pathogenicity in that light infections could be induced in turkeys with limited success, and that the organism was extremely pathogenic to pheasants with 90 percent mortality being produced in groups of pheasants given 80,000 oocysts per bird. However, neither of these studies by Norton provided any information regarding the incidence or level of infection of these species in a population of pheasants raised under field conditions.

Trigg (1967a) presented a detailed account of the life cycle of *Eimeria phasiani*, a common parasite of the pheasant, and in a second study (Trigg, 1967b), he dealt with the pathogenicity and chemotherapy of this parasite. He was able to show that two separate strains of the organism were completely susceptible to Sulfaquinoxaline but less so to Amprolium and Zoaline. He also showed that symptoms and mortality in infected birds varied greatly depending on the size of the infective dose. In experimental infections, he observed marked symptoms in 2 and 3 week old chicks given doses of 100,000 or more oocysts. But again, no quantitative data was presented regarding the incidence or level of infection of this species in a natural population.

Todd and Hammond (1971) reviewed the species of *Eimeria* reported from the pheasant summarizing the data known about distribution, endogenous development, clinical signs, pathogenicity and cross transmission studies.

Recently, Bejsovec (1972) investigated the possible effects of coccidiosis on the replacement of partridges (*Perdix perdix*) by pheasants (*Phasianus colchicus*) in natural populations of game birds in Czechoslovakia. He determined that *E. colchici* was a frequent parasite of the pheasant, and that coccidian infections were common in both pheasants and partridges. He concluded however, that the decreased numbers of partridges and the increased number of pheasants observed in the population he studied were not due to coccidiosis but rather to the abolition of small scale farming, changes in the landscape, and to the introduction of agricultural mass production. Bejsovec reported no detailed information regarding the levels of infection in the pheasants he studied.

Wacha (1973) described the sporulated oocysts of *Eimeria tetartooimia*, and redescribed the sporulated oocysts of *E. pacifica* and *E. duodenalis* from game-farm reared pheasants in Montana, but no reference was made regarding the prevalence of coccidiosis in the pheasants studied.

MATERIALS AND METHODS

During the 20 week period from January 21, 1973, through June 3, 1973, fecal samples were collected from a mixed flock of 150 male and 300 female ring-necked pheasants raised at the Oak View Game-Farm and Shooting Preserve located about 20 miles east of Des Moines in Jasper County, Iowa. The pheasants ranged in age from 9 to 11 months at the beginning of the survey period and were confined for the entire period to a compound completely enclosed by wire. The compound was 5 m. wide, 25 m. long and 2 m. high. In the compound, the pheasants were allowed to move freely. The floor of the compound consisted of tightly packed dirt which varied in consistency depending upon weather conditions, from dry and dusty to extremely muddy to frozen.

During the 5 week survey period from May 6, 1973, through June 3, 1973, 100 newly hatched pheasant chicks, which ranged in age from 1 to 3 days at the beginning of the period, were sampled for coccidian oocysts. All 100 birds were confined to a wire enclosed cage in which the floor was also wire. The cage was 1.5 m. long, 1.5 m. wide and .25 m. high. The hatchlings were maintained on a diet consisting of ground corn, oats, soybean meal, meat and bone meal, and an unmedicated, commercial prescription mix of unknown content prepared by Agritronics Corporation of Des Moines. A coccidiostat, Furazolidone, was combined with the feed. The feed was dispersed in metal troughs attached to the outside wall of the cage. The young birds were provided with water from an inverted self-watering device resting on the floor of the cage. The adult birds were maintained on a diet consisting of the same ingredients except that no coccidiostat was included. Feed for the adult birds was spread on the dirt floor of the compound at daily intervals. Water was provided from uncovered metal troughs placed at varying locations inside the compound. These troughs rested approximately 10 to 15 cm. above the surface of the dirt floor.

For each week, fecal samples were collected by suspending eight porcelain coated metal pans, 25 cm. wide, 45 cm. long and 7 cm. deep, at random locations under the roosts. The pans were covered with wire to prevent the feces from being scratched out of the pans by the birds. The roosts were not sheltered in any way except for the branches of three large trees which grew near the compound. The pans were allowed to remain beneath the roosts for a 48 hour period beginning Friday morning and ending Sunday morning of each week. The contents of each pan were placed in a separate plastic bag and transported to the laboratory for examination. For each sample, the proportion of *Eimeria* species present, and the number of oocysts per gm. of feces were determined. To determine the proportion of *Eimeria* species present, 10 to 15 gms. of each sample were strained and then sporulated at room temperature by placing the strained suspension in a 5 to 10 mm. layer of 2.5 percent potassium dichromate in a finger bowl for about 5 to 7 days. All samples were then refrigerated at about 8° C. until examined. A differential count of the oocysts present in each of the strained samples was then made. The data from each of the samples collected during a given week were combined to obtain the mean differential count for that week. The number of oocysts per gm. was determined by using a modified McMaster's method (Whitlock, 1948; Nyberg, Helfer and Knapp, 1967) in which approximately 15 gms. of fecal material is placed in a separate, pre-weighed, sample jar to which distilled water is added to bring the total volume of the sample to 100 mls. A moderately thick, homogeneous suspension of the sample is then prepared by breaking up the fecal material with a magnetic stirring device. With the aid of a tuberculin syringe, 1.0 ml. of the suspension is transferred to a 2 dram vial containing 2.0 mls. of Sheather's solution, thus bringing the total volume in the vial to 3.0 mls. This mixture was thoroughly shaken, and approximately 1.0 ml. was withdrawn into a second syringe. Both sides of a McMaster's chamber (Hawksley and Sons Ltd., Lansing, Sussex, England; Catalog No. A-11-60) were then charged with this material and the chamber set aside for 5 minutes to allow the oocysts to float to the top of the Sheather's solution. The average number of oocysts counted beneath the calibrated square on each side of the McMaster's chamber represents 1/2000 of the original sample. The number of oocysts per gm. was then determined by the following formula:

$$\text{No. oocyst/gm.} = \frac{\dfrac{\text{No. oocysts, left side of chamber} + \text{No. oocysts, right side of chamber}}{2}}{\text{Wt. of the original sample}} \times 2000$$

As with the differential count, the data from each of the samples examined during a given week were combined to obtain the mean number of oocysts per gm. for that week.

Twice in the survey period, during the fourth week in March and the first week in May, differential counts in 1 of the 8 samples for each of the respective weeks revealed that a number of *Isospora* oocysts almost equalled the number of *Eimeria* oocysts for those samples. In these cases, the two individual samples were excluded from the data for those weeks.

Droppings of feces from the young hatchling pheasants were collected by placing a single pan at a different location beneath the wire mesh floor of the cage each week. The sample was transported to the laboratory and processed in the manner outlined above.

Oocysts appearing in the differential counts were compared to those given in existing descriptions and identified accordingly. Microscopic examination was facilitated with the aid of a compound microscope equipped with an ocular micrometer and achromatic objectives. Photographs were taken with the aid of a Zeiss photomicroscope equipped with Neofluar objectives.

General weather data, used to interpret certain portions of the results, was obtained from the National Weather Service located at the Des Moines Municipal Airport.

DATA

Four species of Eimeria were found to parasitize the ring-necked pheasants at this game-farm and shooting preserve. They were Eimeria phasiani Tyzzer, 1929 (Fig. 1), E. pacifica Ormsbee, 1939 (Fig. 2), E. duodenalis Norton, 1967 (Fig. 3), and E. tetartooimia Wacha, 1973 (Fig. 4). The oocysts identified in this study appear to resemble those of the existing descriptions. Several fecal samples contained a small number of coccidian oocysts resembling those of Isospora lacazei. Twenty of these Isosporan oocysts averaged 23.4 (21.0 to 26.4) by 21.6 (20.0 to 26.0) micrometers in size and had a length/width ratio averaging 1.07 (Range: 1.05 to 1.13). A Stieda body and a finely granular sporocyst residuum were present in the sporocyst. Sporocysts of four of twenty oocysts contained a conspicuous inverted, nipple-like structure which extended into the matrix of the Stieda body. This structure was similar to that described from I. lacazei by Levine (1960). The prevalence of this Isospora species was not determined in the present study. All of the Isosporan oocysts observed in the present study fell within the size ranges given for I. lacazei without exception.

The mean number of oocysts produced per gm. of feces for the 450 pheasants studied during the 20 week survey period is shown in Figure 5. The mean number of oocysts per gm. of feces for the entire study ranged from 156.5 during week 5 to 2410.2 during week 4. The mean number of oocysts produced per gm. of feces for the entire survey was 476.5.

Figures 6 through 9 show the weekly prevalence of the four *Eimeria* species found in the adult pheasants during the 20 week survey period. As indicated in these figures, those species with the highest frequency of occurrence in the flock were *Eimeria phasiani* and *E. pacifica*, each of which had a mean total differential count of 42.0 percent for the entire study. Those species occurring with the lowest frequency were *E. duodenalis* with a mean total differential count of 4.6 percent for the entire survey and *E. tetartooimia* with a mean total differential count of 10.5 percent.

Figure 10 shows the oocyst production in newly hatched pheasant chicks over a 5 week period. No oocysts were seen in the samples at the end of the first week. However, by the end of the second week, the birds were passing over 150,000 oocysts per gm. of feces. This level fell sharply during the last three weeks of the study. Differential counts of the fecal material of the young checks revealed that *E. phasiani* occurred with the greatest frequency comprising 75.0 to 94.0 percent of the oocysts identified for the entire period. *E. pacifica*, *E. tetartooimia*, and *E. duodenalis* occurred with the lowest frequency, all three with percentages less than 10.0.

As noted in Figure 5, three periods of relatively stable oocyst production were observed. The first period includes the last two weeks in January and the first week in February (weeks 1 through 3). The second period includes the third week in February through the third week in April (weeks 5 through 13), and the third period includes the first week in May through the first week in June (weeks 16 through 20). The weather reports obtained for these periods showed the following: During the first period (weeks 1 through 3), the mean daily temperatures averaged -3.3° C. and ranged from -0.3° C. during week 1 to -6.6° C. during week 3. Due to almost 5 cm. of precipitation, in the form of rain or snow, the ground conditions in the compound were very wet during weeks 2 and 3 of the period immediately preceding the time of peak oocyst production which occurred during week 4. During week 4 the floor of the compound was frozen and the mean daily temperatures averaged -8.6° C. During the second period (weeks 5 through 13) the mean daily temperatures averaged 3.7° C., and ranged from -5.5° C. during week 10 to 9.1° C. during week 11. During weeks 5 through 13 the dirt floor of the compound was relatively dry with occasional brief periods of mud due to precipitation. During weeks 12 and 13, the mean daily temperatures averaged 13.7° C. and a severe spring snowstorm left 35 cm. of snow in the compound. These events preceded the second period of peak oocyst production which occurred during weeks 14 and 15. The floor of the compound was extremely muddy during this period due to the precipitation. During the third period of stable oocyst production (weeks 16 through 20) the mean

Figure 1. The sporulated oocyst of *Eimeria phasiani*. X 2000.

Figure 2. The sporulated oocyst of *Eimeria pacifica*. Note striations in outer portion of oocyst wall. X 2000.

Figure 3. The sporulated oocyst of *Eimeria duodenalis*. X2000.

Figure 4. The sporulated oocyst of *Eimeria tetartooimia*. Note polar granule. X 2000.

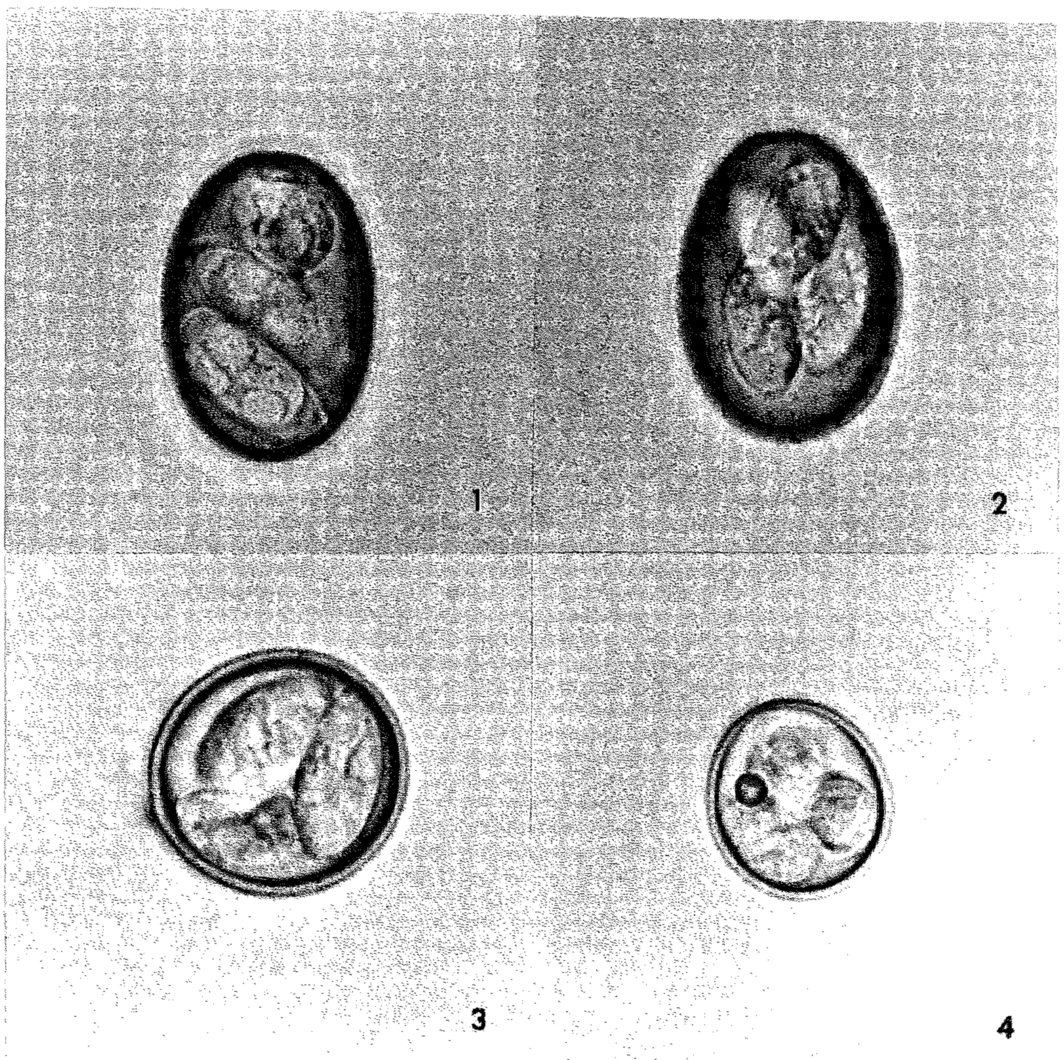

1
2
3
4

FIG 5 OOCYST PRODUCTION IN GAME–FARM REARED ADULT PHEASANTS DURING A 20 WEEK PERIOD BEGINNING JAN. 21 AND ENDING MAY 3, 1973

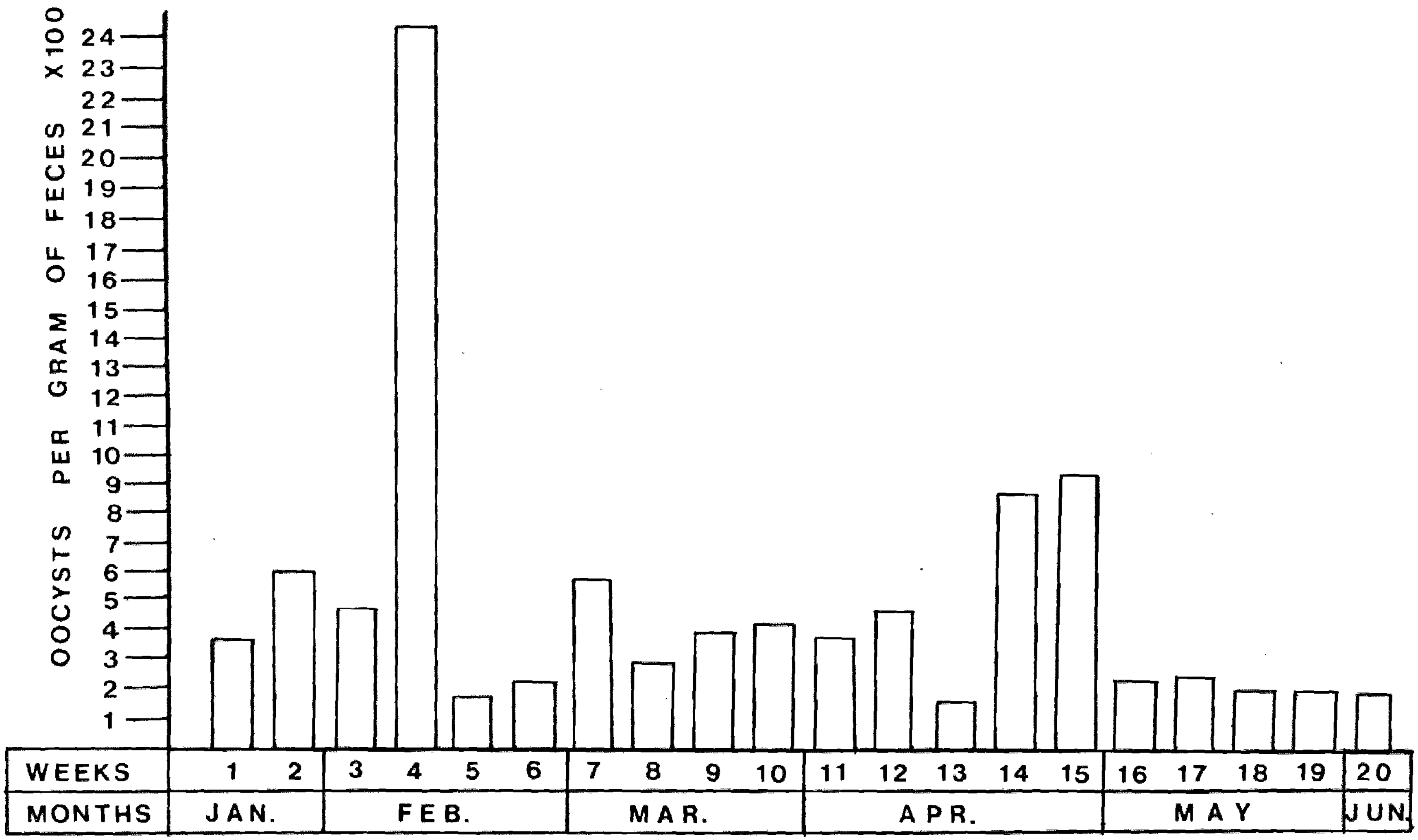


FIG. 6

WEEKLY OCCURRENCE OF EIMERIA PHASIANI IN ADULT PHEASANTS

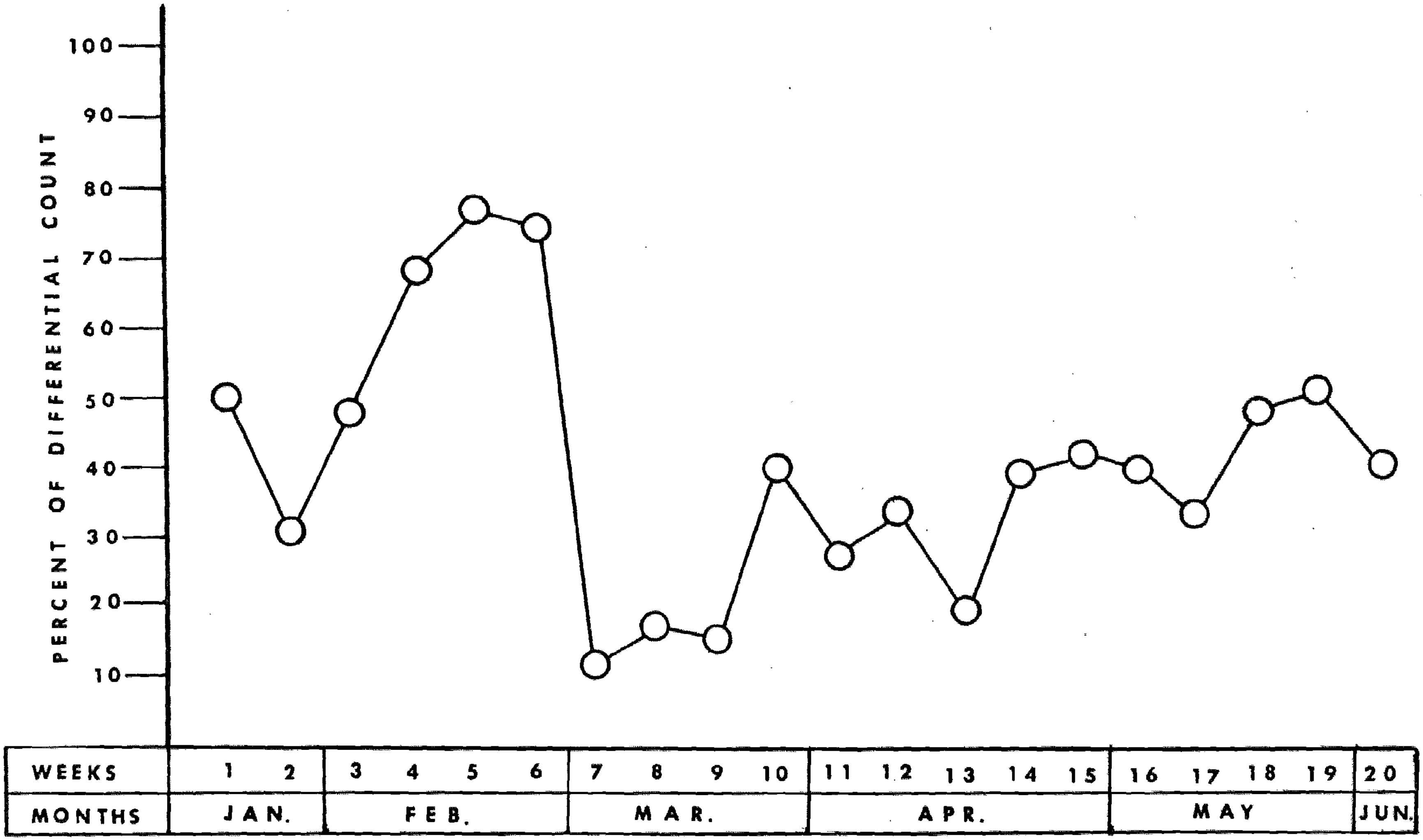


FIG. 7

WEEKLY OCCURRENCE OF EIMERIA PACIFICA IN ADULT PHEASANTS

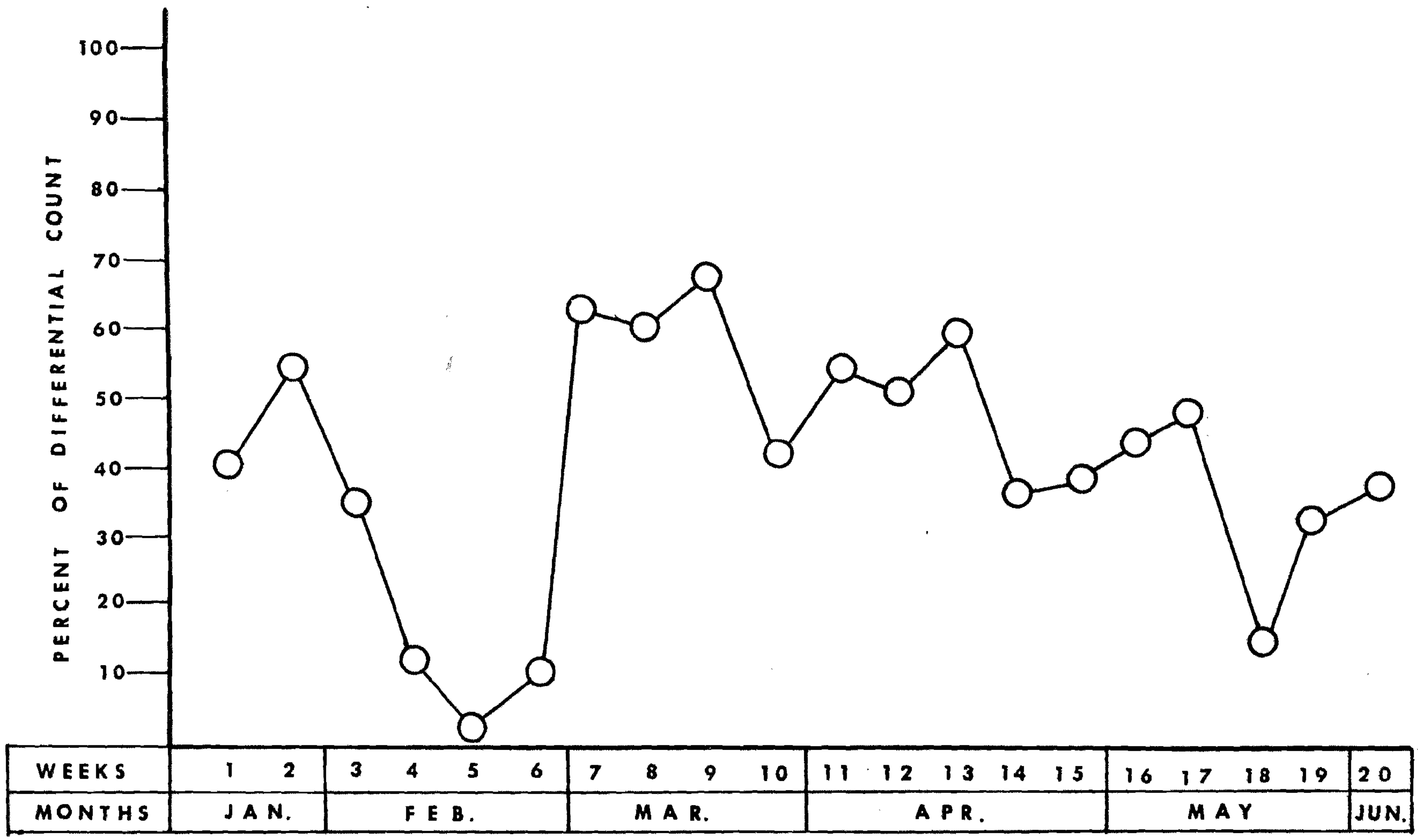


FIG. 8

WEEKLY OCCURRENCE OF EIMERIA DUODENALIS IN ADULT PHEASANTS

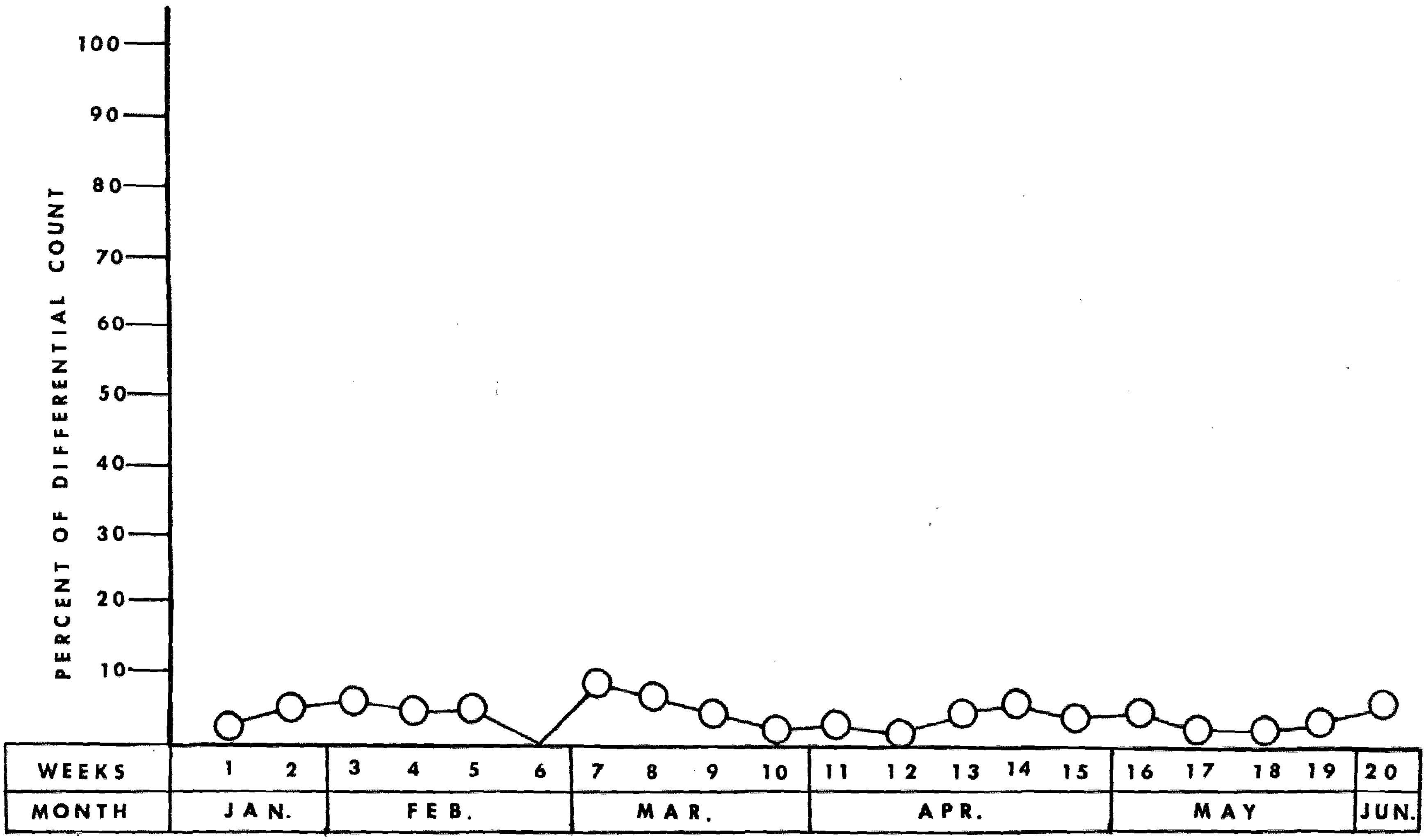


FIG. 9

WEEKLY OCCURRENCE OF EIMERIA TETARTOOIMIA IN ADULT PHEASANTS

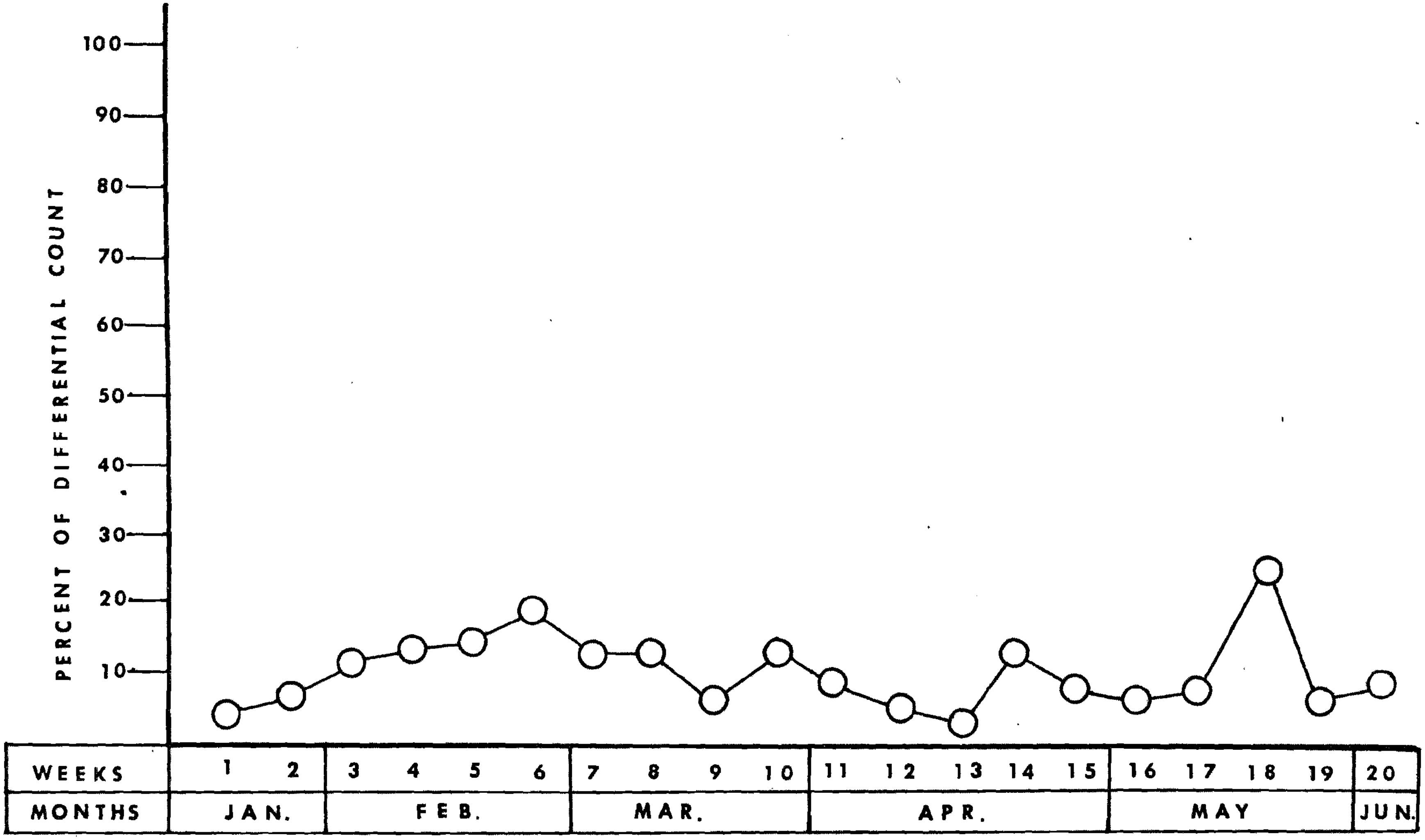
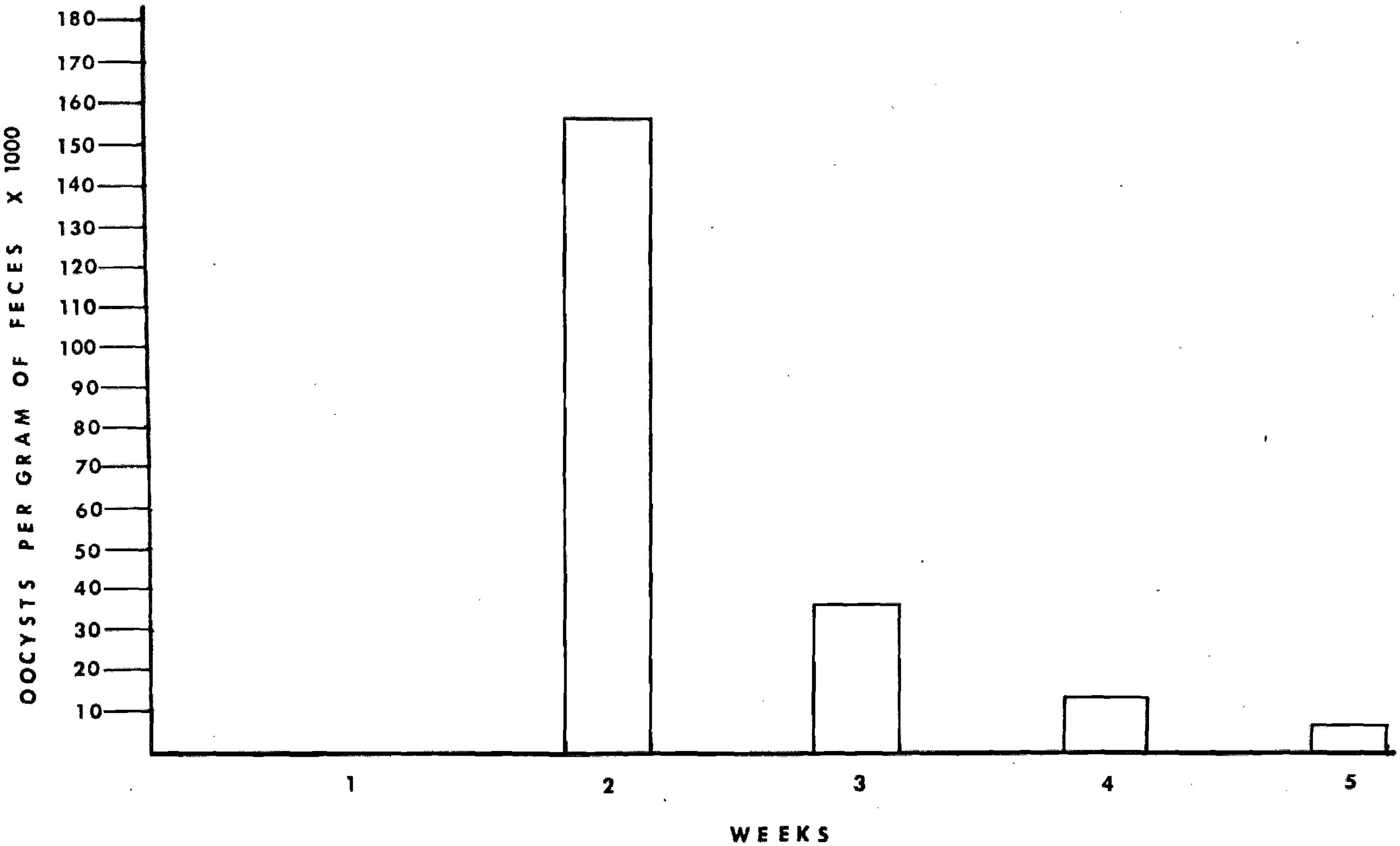


FIG. 10 OOCYST PRODUCTION IN GAME-FARM REARED PHEASANT HATCHLINGS DURING A 5 WEEK PERIOD BEGINNING MAY 5 AND ENDING JUNE 3, 1973



daily temperature averaged 16.6° C., ranging from 9.0° C. to 22.7° C. and the dirt floor was dry.

DISCUSSION

Oocysts belonging to only four of the eight recognized species of *Eimeria* reported to parasitize the ring-necked pheasant were found to be present in this study, viz., *Eimeria phasinai* Tyzzer, 1929, *E. pacifica* Ormsbee, 1939, *E. duodenalis* Norton, 1967, and *E. tetartooimia* Wacha, 1973. Oocysts belonging to *E. dispersa* Tyzzer, 1929, *E. langeroni* Yakimoff and Matschoulsky, 1937, *E. megalostomata* Ormsbee, 1939, and *E. colchici* Norton, 1967, the other four species reported from the pheasant, were not found to be present in this study. In addition to these eight named species, no oocysts resembling the *Eimeria* species reported to have been isolated by McCullough by Davies et al. (1963) and subsequently called "Ex ceca" by Norton (1967b), were observed.

With regard to the four species which were not found to occur in the present study, *Eimeria langeroni* has been reported only from the Soviet Union, and there is only one record of its occurrence there (Yakimoff and Matschoulsky, 1937). In the present study, no oocysts resembling *E. langeroni* were found. The fact that only a single report of *E. langeroni* does exist suggests that this species is either restricted geographically or its occurrence in pheasants is extremely rare. Norton (1967b) thought that _E. langeroni_ might be a synonym of _E. colchici_. However, the size range indicated for the oocysts of _E. langeroni_ appreciably exceeds that indicated for the oocysts of _E. colchici_, and therefore, it is felt that this synonomy is not justified. _E. colchici_ appears to be a parasite of wide distribution in Europe. Bejsovec (1972) found _E. colchici_ to be present in pheasants in Czechoslovakia and Norton (1967b) reported _E. colchici_ from pheasants in England. _E. colchici_ has not been reported from the United States; this parasite was not reported by Ormsbee (1939) who examined the coccidia of wild pheasants in Washington, or by Wacha (1973) who surveyed the coccidian species present in pheasants raised under game-farm conditions in Montana.

There is a strong possibility that _E. colchici_ may be a synonym of _E. pacifica_. The size range reported for the oocysts of _E. pacifica_ fall within the same range as those reported for _E. colchici_. The range reported for the oocysts of _E. pacifica_ was 19.0 to 23.1 by 15.6 to 19.0 micrometers (Wacha, 1973) and 17.0 to 26.0 by 14.0 to 20.0 micrometers (Ormsbee, 1939) while that reported for the oocysts of _E. colchici_ was 19.0 to 33.5 by 13.0 to 21.0 micrometers (Norton, 1967b). Both species were reported to contain a polar granule, and while no micropyle was observed for _E. pacifica_, such a structure was reported for _E. colchici_, but was reported to be inconspicuous in large oocysts of *E. colchici* and apparently not evident in smaller oocysts (Norton, 1967b). In a comparison of *E. colchici* with *E. phasiani*, Norton stated that the oocysts of *E. colchici* could not be mistaken for those of *E. phasiani* even though the size ranges of the two species overlapped. He also stated that the site of infection in the host is different for the two species. It is suggested that while Norton's arguments are valid concerning the comparison of *E. phasiani* and *E. colchici*, his comparison between *E. pacifica* and *E. colchici*, based solely on the morphology of the oocysts, is not. The problem of synonomy between *E. colchici* and *E. pacifica* may be resolved when the endogenous stages of *E. pacifica* are known and can be compared to those of *E. colchici*.

Assuming that *E. colchici* is a valid species, one explanation for its absence in the present study may be its inability to survive in the climatic conditions of the United States. Kheysin (1972) states that different species of *Eimeria* require different optimum temperatures for development. This could be the case with *Eimeria colchici* in the United States. However, the fact that the European and American pheasants were originally introduced from Asia (Edminster, 1954), one would think that both groups of pheasants or their hybrids would show the same coccidia. *Eimeria duodenalis* occurs in both Europe and the United States (Norton, 1967a; Wacha, 1973) while *Eimeria colchici* apparently does not. Also, while E. colchici appears to be a common parasite in Europe (Bejsovec, 1972; Norton, 1967b), E. pacifica appears to be a common parasite in the United States (Ormsbee, 1939; Wacha, 1973). This pattern suggests the possibility that E. pacifica and E. colchici may be one in the same parasite, and if true, according to the taxonomic rules of priority, E. colchici would become a synonym of E. pacifica.

Eimeria megalostomata Ormsbee, 1939, appears to be a species of questionable validity. Ormsbee (1939) stated that oocysts of E. megalostomata and E. pacifica were found together in the pheasants he examined. Furthermore, a histologic study by Ormsbee (1939) showed that the endogenous stages of E. pacifica and those of E. megalostomata appear to infect the same area of the cecum and the same type of host cell. Ormsbee (1939) also stated that "the E. pacifica infection combined with that of E. megalostomata would probably mask the true distribution of E. megalostomata, especially...where there appears to be no great difference between the two species." The size ranges of the oocysts of E. pacifica and E. megalostomata overlap to a great extent (Ormsbee, 1939). According to Ormsbee (1939), the oocysts of Eimeria megalostomata range from 21.0 to 29.0 by 16.0 to 22.0 micrometers while those of E. pacifica range from 17.0 to 26.0 by 14.0 to 20.0 micrometers. Both oocysts were ovoid and contained polar inclusions. The only apparent difference between the two species was the presence of a conspicuously large micropyle in _E. megalostomata_. This structure appears to resemble an indentation in the wall of the oocyst rather than a true micropyle. Since Ormsbee (1939) used a saturated solution of sodium chloride to concentrate his oocysts, this may have caused a collapse of the oocysts walls. Ormsbee (1939) stated that he did have trouble identifying oocysts because of this problem. The strong resemblance of _E. megalostomata_ to the oocysts of _E. pacifica_ coupled with the absence of further reports of _E. megalostomata_, both in the United States and Europe, indicates that _E. megalostomata_ is a synonym of _E. pacifica_ and is hereby declared an invalid species.

Tyzzer (1929) reported that a strain of _E. dispersa_, normally a parasite of the turkey and the quail, from which it was originally described (Tyzzer, 1929), was able to parasitize ring-necked pheasants. However, subsequent attempts to infect pheasants with _E. dispersa_ were unsuccessful (Hawkins, 1952; Moore, 1954), and the oocysts observed by Tyzzer probably were those of another species.

The oocysts reported by McCullough (1952) in Edinburgh and later referred to as _Eimeria_ sp. by Davies et al. (1963) and "Ex ceca" by Norton (1967b) were thought by Norton to be oocysts of _E. colchici_ (Norton, 1967b).

Ormsbee (1939) reported three unusual oocysts from a bird harboring an infection of _E. phasiani_. These three oocysts averaged 18.0 by 15.0 micrometers in size and contained one polar granule. He simply designated these as "Type IV." These oocysts bear such a close resemblance to those of E. tetartooimia described by Wacha (1973) that they probably belong to the same species. This resemblance is identified by the name "tetartooimia" meaning "like the fourth."

Regarding the production of oocysts in the adult birds of this study, three relatively stable periods of low oocyst production, separated by two brief periods of high oocyst production, were observed (Fig. 5). These periods of high oocyst production may have resulted from certain weather conditions which occurred during the weeks immediately preceding these periods. During the second and third week of the study (the last week in January and the first week in February), the mean daily temperatures ranged between -5.5° C. and -5.0° C. This was in rather sharp contrast to the -0.3° C. to 0° C. temperatures reported for the first week of the study. Following this sharp drop in temperature during these two weeks, the mean number of oocysts produced in the flock rose to its highest point for the entire survey. This drop in temperature in combination with damp conditions resulting from the presence of snow in the compound may have caused the bird's resistance to infection to decrease to the extent that increased oocyst production took place. These conditions of stress may have produced a situation analagous to that causing winter coccidiosis in cattle. Fitzgerald (1962) states that one of the most important factors in the epidemiology of coccidiosis is the climatic conditions under which the host animals are maintained. Winter coccidiosis is a term applied to an increased coccidian infection which occurs during stress periods such as during the winter months when the temperatures drop.

During the thirteenth, fourteenth and fifteenth weeks of the study (the third through the fifth weeks in April), the oocyst count increased from about 200 oocysts per gm. of feces to about 900 oocysts per gm. As with the first period of increased oocyst production described above, severe weather conditions prevailed during the period immediately preceding the second increase. During the second week in April, a severe spring snowstorm left 35 cm. of snow on the floor of the compound. This precipitation was followed by unseasonably warm mean daily temperatures ranging from 1.6° C. to 12.7° C. for the remainder of the month. These conditions had the effect of making the dirt floor of the compound into a sea of mud for a period of about three weeks. During this time, the birds were probably not adversely affected by the temperature, but rather indirectly affected by the muddy condition of the floor of the compound which would tend to favor the survival of large numbers of oocysts which would normally have undergone desication. Soil moisture, along with a high relative humidity, are probably the most important conditions with regard to the survival of coccidian oocysts (Kheysin, 1972). Possible lowered resistance in the pheasants due to trauma and stress resulting from the storm in combination with the possible accumulation of viable oocysts, due to their increased survival, may have contributed to this second increase in oocyst production.

With regard to the three periods of stable oocyst production (weeks 1 through 3, 3 through 13, and 16 through 20), little fluctuation in the number of oocysts produced was observed. Little fluctuation was also observed in the general weather patterns. However, when the climatic conditions were abruptly altered, as happened during the brief periods preceding weeks 4 and 14 of the study, oocyst production reached its highest levels.

Oocyst production observed for a 5 week period in 100 newly hatched pheasant chicks is illustrated in Figure 10. No oocyst production in the young birds was observed at the end of the first week. However, at the end of the second week, during which time the pre-patent period of infection would have ended, production of oocysts increased to about 150,000 per gm. of feces. This level decreased markedly during the following three weeks to a low of about 500 oocysts per gm. at week 5. Such a reduction in oocyst numbers would be expected since the birds were being maintained on a coccidiostat, Furazolidone, and were being raised on wire. This reduction in oocyst number was undoubtedly due in part to increased immunity resulting from exposure to infection. The initial coccidian infection in the young birds was probably obtained from the presence of infective oocysts on the wire mesh which made up the walls and floor of the cage and from contamination of the feed. These oocysts could have remained viable for some period of time since the cages were housed in an environment which had a high relative humidity during the remainder of the growing season. Kheysin (1972) states that oocysts of several species of *Eimeria* are capable of remaining infective for up to 5 months and even longer under favorable, natural conditions.

Of the 100 young birds sampled, about 10 percent exhibited clinical signs of coccidiosis (Personal communication with the game-farm administrator). No deaths were attributed to coccidiosis, however, According to Norton (1967a) and Trigg (1967b), clinical signs of coccidiosis occur when the oocyst dose exceeds 50,000 oocysts for *E. duodenalis* and 25,000 oocysts for *E. phasiani*. The pathogenicity of *Eimeria pacifica* and *E. tetartooimia* has not been studied.

According to the weekly differential counts, *E. phasiani* (Figs. 1 and 6) and *E. pacifica* (Figs. 2 and 7) appear to be the most prevalent of the four species observed in the adult birds, while *E. tetartooimia* (Figs. 4 and 9) and *E. duodenalis* (Figs. 3 and 8) appeared to be the least prevalent.

It is interesting to note that _E. phasiani_ and _E. pacifica_ (Figs. 6 and 7) reveal a cyclic pattern of occurrence with respect to their prevalence at several points. For example, Figure 6 shows a high percent of _E. phasinai_ oocysts present during the last three weeks in February while Figure 7 shows a correspondingly low percent for _E. pacifica_ during the same period. Similarly, the first three weeks in March appeared to be the least favorable for _E. phasiani_ in terms of percent of oocysts present, while this same period was the most favorable for _E. pacifica_. The remainder of the investigation shows a similar pattern for succeeding weeks but on a smaller scale. It is apparent that, throughout the survey period, _E. phasiani_ and _E. pacifica_ alternate with regard to their prevalence in the adult birds. Other than a possible cyclic pattern of immunity in response to these parasites by the host, little information is available to explain this phenomenon. However, the occurrence of this cyclic pattern would suggest that little cross immunity exists between _E. phasiani_ and _E. pacifica_. The influence of weather conditions in this cyclic pattern is not known, however, it should be observed that this cyclic pattern is most noticeable during the coldest months of the survey period. This cyclic pattern between _E. phasiani_ and _E. pacifica_ appears to be one of the more interesting aspects of the multiple infections observed in the present study.

E. duodenalis (Fig. 8) and *E. tetartooimia* (Fig. 9) fail to show any consistent cyclic pattern either between themselves or between the other species. A slight trend is seen, however, in Figures 6 and 9 in which certain peaks of *E. tetartooimia* (Fig. 9) correspond to those of *E. phasiani* (Fig. 6). However, this relationship is not consistent. More work, including statistical comparisons of specific oocyst populations must be completed in order to draw any conclusions as to the significance of these patterns.

E. phasiani dominated the differential counts of the samples taken from the young birds. However, patterns of oocyst distribution resembling those in the adults were not observed.

A small number of Isosporan oocysts resembling those of *I. lacazei* described by Levine and Mohan (1960) were found in the present study. The Isosporans of the present study are thought to belong to one or more species of passeriform birds roosting in close proximity to the pheasants. The fact that birds of this order, such as the starling (*Sturnus vulgaris*) and the sparrow (*Passer domesticus*), were observed to perch above the compound in which the pheasants were maintained plus the fact that species of *Isospora* have not been confirmed to infect galliform birds (Todd and Hammond, 1971), suggests that the *Isospora* species observed herein is not a parasite of pheasants, but rather a contaminant species. No *Isospora* species were seen in those samples taken from the young birds. Fecal samples of the various species of passeriforme birds present at the game-farm were not examined.

CONCLUSIONS

Four species of *Eimeria* were found to parasitize the ring-necked pheasants raised under game-farm conditions in this survey. They are *Eimeria phasiani*, *E. pacifica*, *E. duodenalis*, and *E. tetartooimia*. The mean number of oocyst produced per gm. of feces for the entire survey was 476.5. *E. phasiani* and *E. pacifica* were the most prevalent species, each averaging about 42.0 percent of the total weekly differential counts. *E. tetartooimia* and *E. duodenalis* were the next most prevalent species comprising 10.5 and 4.0 percent of the total weekly differential counts respectively.

With regard to oocyst production, there appears to be a correlation between stable periods of oocyst production and stable conditions of climate. If the environmental conditions are abruptly altered, as observed twice during this study, oocyst production appears to be affected. In the present study, adverse weather conditions appeared immediately prior to an increase in oocyst production. Immunity appears to be well established in the young birds within 5 weeks after hatching as indicated by the marked decrease in oocyst production within that time. Presumably, a state of premunition is established in the hosts during this time. *E. phasiani*, alone, dominated the differential counts of the samples taken from the young birds in a five week survey.

As with most diseases, several factors undoubtedly influenced the epidemiological patterns observed in the coccidian infections at this game-farm, and as with most infections, climate, host resistence and immunity, chemotherapy, and management were among these factors. The extent to which these factors were operative is only suggested by this study and a statistical comparison of these factors with the prevalence of each of the species found is necessary before any valid epidemiological patterns can be assumed as factual.

Coccidian oocysts resembling those of *Isospora lacazei* were found in small numbers in the sample pans of this study. These oocysts are believed to be contaminants from one or more species of passeriforme birds which occasionally perched above the compound in which the pheasants were penned.

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